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AN EXPANSION OF THE EV SYSTEM

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SUMMARY

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The exposure value system or additive value system has been expanded to include filter factors and transmittance. In addition, the equations for photoflash and electronic flash photography are converted into a form compatible with the EV system. The photographic factors are presented in tabular form together with their corresponding values in the additive value system in 25-percent steps or quarter stops to permit an acceptable solution to be obtained more readily.

INTRODUCTION

In the utilization of photography in research, unusual conditions are encountered that in some cases range from making exposures of about 0.01 second of objects having brightness levels of the order of 100 times brighter than a beach scene, to other unrelated situations. Generally for these conditions a correct exposure for a given time and film is determined experimentally and it is often required to transpose these settings to another one involving changes in film and exposure time. It appeared that this transposition could be accomplished more rapidly and with less restriction on the variation of the variables involved if an additive system such as the exposure value (or light value) system could be used.

This application of the exposure value system however required that the system be extended to high brightness level, and expanded to include filter factors. Exposure values especially in tabular form (refs. 1 and 2) have been in steps of 1 or one stop. A minimum of four photographic factors are involved in the evaluation of an exposure which when determined from tables of 1-stop interval could introduce noticeable error. It was desirable therefore that the values be provided in 25-percent steps or quarter stops to permit an acceptable solution to be obtained more readily. The initial study in 1960 produced numerical values in 0.25 increment of exposure for each of the following photographic factors: f/number, exposure time, film speed, object brightness, and filter factor. Since then the analysis has been expanded to include the factors involved in photoflash and electronic flash photography.

This paper presents the derivation of the equations relating the photographic factors for both basic photography and flash photography. These equations are converted into an additive value system that is a duplicate of or is compatible with the exposure value system. Tabulated values are presented of the photographic factors and their corresponding values in the additive system which permit the application of the expanded system to photographic problems within ranges wherein the reciprocity effects are approximately constant.

SYMBOLS

A_v	aperture value, $f = 2^{A_v/2}$
b	brightness of object (subject), candles/ft^2
B_v	brightness value, $b = 0.3515 \times 2^{B_v}$
c	transmittance factor, ratio of incident light to transmitted light
C_v	transmittance value, $C = 2^{-C_v}$
d	diameter of lens, or free aperture, ft
D	distance from flash to object (subject), ft
D_v	distance value, $D = 2^{D_v/2}$
E_v	exposure values (also EV), $E_v = A_v + T_v = B_v + S_v$
f	f/number, l/d
F	light flux output of source, lumens
F_v	flash value of photoflash bulb, $L = 12.5 \times 2^{F_v}$
G	guide number for flash, $G = f \times D$

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G_v guide value, $G = 2^{G_v/2}$

i image distance or lens to film distance, ft

k a constant

l focal length of lens

L_e lumen-second output of electronic flash

L_p lumen-seconds output of photoflash bulbs

L_v light value, interchangeable with E_v in popular usage, also LVS

N_v the numerical value expressed in the additive or EV system that is derived from any photographic factor, $N_v = 0$ for $t = 1$ $(T_v = 0)$, $f = 1$ $(A_v = 0)$, $s = 3$ $(S_v = 0)$, etc.

O object distance from lens, ft

P_i area of image, sq ft

P_s area of object or subject, sq ft

Q beam candle power seconds output of electronic flash

Q_v electronic flash value, $Q = 5 \times 2^{Q_v}$

r reflectivity of object or subject (used as 17.7%)

s film speed ASA rating, $s = \frac{k}{\text{Exposure}}$

S_v speed value of film (often denoted by the superscript ^{o}), $s = 3.125 \times 2^{S_v}$

t exposure time, seconds

T reciprocal of exposure time, $1/t$

T_v exposure time value, $T = 2^{T_v}$

W reflector factor $= \frac{\text{Illuminance with reflector}}{\text{Illuminance without reflector}}$

x filter factor

X_v filter value, $x = 2^{X_v}$

Subscript:

o numerical value of a photometric factor for which $N_v = 0$ or for which its contribution to the exposure value is zero

DERIVATIONS

In the application of the exposure value system to cameras and exposure meters, an EV number is determined by a combination of exposure time and the f/number of the lens. A light value or exposure value is also determined by a combination of object brightness and film speed. For a successful exposure the two exposure values must be equal; therefore, the basic photometric relation between the four photographic factors is needed before the contribution of each factor to the exposure value can be determined and the system expanded. The presentation of the derivations will in themselves indicate limitations on the application of the system, as well as provide a foundation for future expansion.

Basic Photometric Relation

An object or surface of uniform luminance b (candles/ft^2) having an area P_s is located on and normal to the optical axis of a perfect lens of diameter d at a distance O from the lens (with linear dimensions in feet).

The illuminance on the lens is

$$\frac{bP_s}{O^2} \text{ lumens/ft}^2.$$

The luminous flux passing through the lens is $\frac{bP_s}{O^2}\frac{\pi d^2}{4}$ lumens.

An image of area P_i will be formed on the film, having an intensity of illumination of

$$\frac{bP_s}{O^2}\frac{\pi d^2}{4P_i}\frac{\text{lumens}}{\text{ft}^2}.$$

From geometric optics the object and image areas are related by $P_s i^2 = P_i O^2$ where i is the image to lens distance and is approximately equal to the focal length of the lens. $i \approx l$ but $f = l/d$ then $i \approx fd$.

The intensity of illumination in the image on the film is $\frac{\pi}{4}\frac{b}{f^2}$ lumens/ft^2

If the illumination is incident upon the photographic film at the image plane for a time t seconds, the film exposure is the product of the intensity of illumination and the duration of the exposure.

$$\text{Exposure} = \frac{\pi bt}{4f^2} \text{ foot candle seconds.}$$

The ASA (American Standards Association) speed rating of the film s by definition is inversely proportional to the exposure or

$$s = \frac{k_1 f^2}{bt}$$

The graduations of the dials on exposure meters used for computing exposure, as well as the calibrations of the meters, are based on this equation. When t is in seconds, s is the effective ASA speed rating and b is in candles/ft^2 the value of the constant k_1 is about 1.05 with variations in practice ranging from 1.0 to 1.1. The differences however do not constitute any significant effect upon exposure. A value of about 1.1 will be used herein in order to retain compatibility with the tables of references 1 and 2 on incident light and have a reflectivity approximately that of the standard gray card (about 18%).

The basic photometric equation is

$$\left.\begin{aligned} 1.1f^2 &= bts \\ \text{or} \quad 1.1Tf^2 &= bs \end{aligned}\right\} \tag{1}$$

The effective ASA rating depends upon reciprocity and in some applications can be affected by differences between the spectral response of the film and the spectrum of the luminance of the object.

The Exposure Value or Light-Value System

General Photography

The system is designated in various ways on exposure meters and on cameras as EV, LVS, EV-LVS, Light-Value. An EV number for a camera is fixed by any combination of exposure time t and f/number for which Tf^2 = constant. On exposure meters for a given film speed the brightness also defines a value which is sometimes called the light value. The numerical value depends on the product of brightness and film speed ($b \times s$). The "value system" will be referred to herein as the EV system for simplicity, and a particular exposure value or light value will be denoted as E_v.

An analysis of the EV system shows that

$$Tf^2 = 2^{E_v} \tag{2}$$

so that $Tf^2 = 1$ for $E_v = 0$.

Datum or base values were determined for T, f, s, and b corresponding to $N_v = 0$ (also $E_v = 0$) and designated by the subscript o which, combined with equations (1) and (2), becomes

$$T_o f_o^2 = 0.91 b_o s_o = 1$$

The values for $N_v = 0$ (also $E_v = 0$) are

$$T_o = 1, \quad f_o = 1, \quad b_o = 0.35, \quad s_o = 3.125$$

The corresponding values given in references 1 and 2 for exposure time and film speed are 1 second and ASA of 3 which are in agreement. The derived value for b_o from reference 2 is 0.3125.

Since $T_o f_o^2 = 1$ and $Tf^2 = 2^{E_v}$ then $\frac{T}{T_o} \times \frac{f^2}{f_o} = 2^{E_v}$. Now E_v can be resolved into the individual components that correspond to the separate photometric factors as

$$T/T_o = 2^{T_v} \quad \text{and} \quad f^2/f_o^2 = 2^{A_v}$$

$$2^{E_v} = 2^{T_v} \times 2^{A_v} = 2^{T_v + A_v}$$

$$E_v = T_v + A_v$$

Similarly

$$b/b_o = 2^{B_v} \quad \text{and} \quad s/s_o = 2^{S_v}$$

$$b/b_o \times s/s_o = T/T_o \times f^2/f_o^2 = 2^{B_v} \times 2^{S_v}$$

hence

$$E_v = T_v + A_v = B_v + S_v \tag{3}$$

These permit the EV system to be extended in range and to be evaluated in smaller steps than are usually available.

Sometimes it is desirable to include filter factor x, and the transmittance of other elements in the optical path c. The basic equation becomes

$$KTf^2x = bsc$$

for

$$N_v = 0 \quad x_o = 1 \qquad c_o = 1.0 \text{ or percent/100}$$
$$x/x_o = 2^{X_v} \qquad c/c_o = 2^{-C_v}$$

and

$$E_v = A_v + T_v + X_v = B_v + S_v - C_v \tag{4}$$

Photoflash Photography

Consider a light source of F lumens illuminating an object at a distance of D feet

The intensity of the source is $F/4\pi$ candles.

The illuminance on the object is $F/4\pi D^2$ foot candles.

The luminance of the object having a reflectivity of r is $rF/4\pi D^2$ lumens/ft^2 and $b = rF/4\pi^2 D^2$ candles/ft^2.

With $r = 17.7\%$ and using a reflector behind the lamp that increases the illuminance on the object by a factor W the luminance becomes

$$b = WF/223D^2$$

Substituting in the basic photometric equation (1) $1.1f^2 = bts$ gives $f^2D^2 = WFts/257$.

The total output of a photoflash bulb is expressed in lumen seconds L_p. When the exposure time of the shutter is 1/30 second or longer as in open flash, the actual exposure time is determined by the duration of the flash (excluding FP type bulbs). Then $L_p = Ft$ and $f^2D^2 = WL_ps/257$.

The guide number of flash bulbs G is specified by manufacturers of the bulbs as a function of film speed s, and is by definition

$$G = f \times D$$

Thus

$$G^2 = f^2D^2 = 0.0039WL_ps$$

A compilation of values of G, L_p, and s recommended by manufacturers of photoflash bulbs for 6- to 7-inch polished reflectors produced an empirical value 0.025 for 0.0039W. A recent publication (ref. 3) gave the value as 0.005W with W varying from four to seven, depending on the (polished) reflector and flashbulb combination.

For efficient reflectors the relation will be

$$G^2 = f^2D^2 = 0.025L_ps \qquad (5)$$

This equation can be resolved into a form compatible with the EV system as follows:

Since ${f_o}^2 = 1$ and $s_o = 3.12$ at $N_v = 0$.

Let ${D_o}^2 = 1$.

Then ${G_o}^2 = 1$ and $L_{po} = 12.5$ lumen-seconds.

Now $G/{G_o}^2 = 2^{G_v}$, $D/{D_o}^2 = 2^{D_v}$ and $L_p/L_{po} = 2^{F_v}$.

Since $G/{G_o}^2 = f/{f_o}^2 \times D/{D_o}^2 = L_p/L_{po} \times s/s_o$
$2^{G_v} = 2^{A_v} \times 2^{D_v} = 2^{F_v} \times 2^{S_v}$.

Hence

$$G_v = A_v + D_v = F_v + S_v \qquad (6)$$

The basic value assigned L_o ($F_v = 0$) is for open flash onto an average subject. The usual recommendations for subjects reflecting more or less light are to decrease the aperture 1/2 stop for light subjects and increase the aperture 1/2 stop for dark subjects.

On the EV scales this correction becomes:

For light subjects - add 0.5 to F_v or G_v.

For dark subjects - deduct 0.5 to F_v or G_v.

Open-flash requires that the entire film frame be exposed for 1/30 of a second or greater for any leaf-type shutter at M or X synchronization settings. Focal-plane shutters pose problems that can vary depending upon the design of the shutter and are consequently not included in this general discussion. For shutters other than focal-plane types, shorter exposures than the open-flash can be obtained with the M-delay shutter for which the shutter opening is delayed about 14 milliseconds after contact is made for the flash bulb. Some M designated shutters can vary from the 14 ms delay by design. The recommended guide numbers for flash bulbs vary with exposure time of M-shutters as well as with film speed, the variations can be simplified for the EV or additive value system as approximate corrections as follows to be deducted from F_v:

t	1/30	1/60	1/125	1/250
ΔF_v	0	0.5	1.0	1.5

Electronic Flash

The light output of an electronic flash unit is expressed in lumen-seconds L_e or in beam candle power seconds Q. The latter unit is usually abbreviated as BCPS and its symbol used herein is Q. The electronic flash light output differs from the lumen-seconds of a photoflash bulb L_p in that Q or L_e is directed and not approximately spherically distributed as is L_p. Also Q or L_e include the reflector factor W used in the photoflash derivation.

The derivation of the photometric equation for guide number G parallels the photoflash lamp derivation, and produces these results:

$$\frac{1.1f^2D^2}{s} = \frac{r}{4\pi^2} WL_p = \frac{r}{4\pi^2} L_e = \frac{r}{\pi} Q$$

The guide number for the electronic flash is:

$$G^2 = f^2D^2 = 0.0041L_es = 0.051Qs$$

In actual practice and in accordance with recommendations of various film and flash unit manufacturers these become

$$G^2 = f^2D^2 = 0.0064L_es = 0.064Qs \qquad (7)$$

Reference 3 gives $G^2 = 0.063Qs$ while reference 4 gives $G^2 = (0.067 \text{ to } 0.040)Qs$.

The electronic flash equation can be reduced to an additive form compatible to the EV system.

For $N_v = 0$, $G_o = 1$ and $s_o = 3.125$

$$0.064Q_o \times 3.125 = 1$$

$$Q_o = 5.0 \text{ BCPS}$$

and

$$Q/Q_o = 2^{Q_v}$$

Hence

$$G_v = A_v + D_v = Q_v + S_v \qquad (8)$$

It is also obvious from the equation that in practice

$$Q = 0.1L_e$$

so that lumen-seconds can easily be converted into BCPS.

The watt-second rating given for electronic flash units is usually the power input. The output Q will depend on the overall efficiency. The overall efficiency has wide variations, 1 watt-second can produce from 10 to 38 beam candle power seconds in production units.

APPLICATIONS

Base values or datums for each of the photographic factors denoted by the subscript o were determined such that the numerical contribution of that factor to the exposure value or the additive system value was zero and for which it was specified that N_v was zero. The choice of $N_v = 0$ for the datum permits one column in a table with the heading N_v to contain the additive values for each and every photographic factor included in the table.

In the derivations it was specified that:

$T = T_o \times 2^{T_v}$, $f^2 = f_o^2 \times 2^{A_v}$, $b = b_o \times 2^{B_v}$, $s = s_o \times 2^{S_v}$, - - -.

Also by definition these can be expressed as:

$T = T_o \times 2^{N_v}$, $f^2 = f_o^2 \times 2^{N_v}$, $b = b_o \times 2^{N_v}$, $s = s_o \times 2^{N_v}$, - - -.

The table contains values of each of the various photographic factors and a column headed N_v. The numerical values of the factors are presented in increasing or decreasing steps that correspond to a change in N_v of 0.25 which represents a 25-percent change in exposure or in photographic terminology a quarter stop.

The numerical values of the photographic factors in the table were obtained by multiplying the base value of the factor by 2^{N_v}. The values thus obtained were somewhat rounded either by dropping figures of no significance or by shifting to standard numbering. The numbers presented closely represent geometric progression of the values.

The numbers in the columns corresponding to whole numbers of N_v from 0 to 10 for incident light, film speed, exposure time, and f/number duplicate in almost all cases those of references 1 and 2. The luminance values in candles/ft^2 of reference 2 are somewhat lower and the differences correspond to a decrement in reflectance of 2 percent.

The table applied to the equations are derived herein and are summarized as follows:

For general photography equation (4) is: $E_v = T_v + A_v + X_v = B_v + S_v - C_v$.

To obtain values for equation (4) from the table use: $E_v = N_v$ for $T + N_v$ for $f + N_v$ for $x = N_v$ for $b + N_v$ for $s - N_v$ for c.

For photoflash using an efficient reflector equation (6) is: $G_v = A_v + D_v = F_v + S_v$.

To obtain values for equation (6) from the table use: N_v for $G = N_v$ for $f + N_v$ for $D = N_v$ for $L_p + N_v$ for s.

For electronic flash equation (8) is: $G_v = A_v + D_v = Q_v + S_v$.

When using the table for equation (8) adopt this procedure: N_v for $G = N_v$ for $f + N_v$ for $D = N_v$ for $Q + N_v$ for s.

The photoflash equation (6) is for open flash with exposures of 1/30 second or longer for X or M synchronization. Shorter exposure times can be used with M synchronized shutters if the following correction is deducted from the flash value:

t	1/30	1/60	1/125	1/250
ΔF_v	0	0.5	1.0	1.5

Thus for M-synchronization equation (6) becomes

$$G_v = A_v + D_v = F_v - \Delta F_v + S_v$$

Examples of application of equation (4).

A camera was used to photograph a luminous object. A correct exposure was obtained on a film having a speed rating of 200 ASA with the lens at f/32 using two filters having filter factors of 10 and 4. The exposure time was 1/200 second.

To estimate what filter factor to use in obtaining motion pictures on an ASA 160 film at 1/3600 second (278 μsec) exposure at the same f/number of 32

$t = 1/200 \qquad f/32 \qquad x = 10 \text{ and } 4 \qquad s = 200$

$T_V = 7\frac{3}{4} \qquad A_V = 10 \qquad X_V = 3\frac{1}{4} + 2 \qquad S_V = 6$

$E_V = 23 \quad B_V = 23 - 6 = 17 \quad b = 46{,}000 \text{ candles/ft}^2$

$t = 278\ \mu\text{sec} \qquad f/32 \qquad b = 46{,}000 \qquad s = 160$

$T_V = 11\frac{3}{4} \qquad A_V = 10 \qquad B_V = 17 \qquad S_V = 5\frac{3}{4}$

$$E_V = 22\frac{3}{4}$$

$X_V = 22\frac{3}{4} - 21\frac{3}{4} = 1$

$x = 2$

A Kerr cell camera was used to obtain a photograph at f/8 on ASA 3000 film at an exposure of 0.1 μsec. The transmittance of the cell is 10 percent. If the aperture is limited by the Kerr cell to f/4.5 what is the least exposure time permitted? In another case with a light amplification system having an amplification factor of 2 what aperture would be used at 0.05 μsec exposure? It is assumed that reciprocity effects are constant within the range of exposure time (0.1 to 0.05 μsec).

$t = 0.1\ \mu\text{sec} \qquad f/8 \qquad s = 3000 \qquad c = 10\%$

$T_V = 23\frac{1}{4} \qquad A_V = 6 \qquad S_V = 10 \qquad C_V = 3\frac{1}{4}$

$E_V = 29\frac{1}{4}$

for $f/4.5 \quad A_V = 4\frac{1}{4} \quad T_V = 25 \quad t = 0.03\ \mu\text{sec}$

least time. $E_V = 29\frac{1}{4} \quad B_V + S_V = 29\frac{1}{4} + 3\frac{1}{4} = 32\frac{1}{2}$.

An amplification of two corresponds to a transmittance of 200% or a $C_V = -1$.

$$B_V + S_V - C_V = 32\frac{1}{2} + 1 = 33\frac{1}{2} = E_V$$

$t = 0.05\ \mu\text{sec} \qquad T_V = 27\frac{1}{2}$

$$A_V = E_V - T_V = 6$$

The aperture would be eight.

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2^{N_v}	Transmittance c, percent	Electronic flash Q, BCPS	Photoflash L, lumen-sec	Incident light $b \times \pi/r$, ft-candle	Reflected light b, candles/ft^2	Film speed s, ASA	N_v value	t, sec	f, f/no.	D or G ft. or Guide No.	Filter factor, x
0.0625	1600		0.78	0.39	0.022	0.20	-4	16	0.25	0.25	
.0744	1345		.93	.46	.026	.23		13.5	.27	.27	
.0884	1130		1.1	.55	.031	.28	.5	11.3	.30	.30	
.1052	950		1.3	.66	.037	.33		9.5	.32	.32	
.1250	800		1.5	.78	.044	.39	-3	8	.35	.35	
.1487	673		1.8	.93	.052	.46		6.7	.38	.38	
.1768	565		2.2	1.1	.062	.5	.5	5.7	.42	.42	
.2103	475		2.6	1.3	.074	.7		4.8	.45	.45	
.250	400		3.1	1.6	.088	.8	-2	4	.50	.50	
.2973	336		3.7	1.9	.10	.9		3.4	.55	.55	
.3536	283		4.4	2.2	.12	1.1	.5	2.8	.59	.59	
.4205	238		5.3	2.6	.15	1.3		2.4	.65	.65	
.500	200		6.2	3.1	.18	1.6	-1	2	.71	.71	
.5946	168		7.4	3.7	.21	1.8		1.7	.77	.77	
.7071	141		8.8	4.4	.25	2.2	.5	1.4	.84	.84	
.8409	119		10.5	5.3	.30	2.6		1.2	.92	.92	
1	100	5	12	6	.35	3	0	1	1	1	1
1.189	84	6	15	7	.42	4		1/1.2	1.1	1.1	1.2
1.414	70.7	7	18	9	.50	4	.5	1/1.4	1.2	1.2	1.4
1.682	60	8	21	10	.59	5		1/1.7	1.3	1.3	1.7
2	50	10	25	12	.70	6	1	1/2	1.4	1.4	2.0
2.378	42	12	30	15	.84	7		1/2.4	1.5	1.5	2.4
2.828	35	14	35	17	.99	9	.5	1/2.8	1.7	1.7	2.8
3.364	30	17	42	21	1.18	11		1/3.4	1.8	1.8	3.4
4	25	20	50	25	1.40	13	2	1/4	2	2	4.0
4.757	21	24	59	29	1.67	15		1/4.8	2.2	2.2	4.8
5.657	18	28	70	35	2.0	18	.5	1/5.7	2.4	2.4	5.7
6.727	15	34	84	42	2.4	21		1/6.7	2.6	2.6	6.7
8	12	40	100	50	2.8	25	3	1/8	2.8	2.8	8
9.514	10	48	119	56	3.3	30		1/9.5	3.0	3.0	9.5
11.314	8.8	57	141	70	4.0	36	.5	1/11.3	3.4	3.4	11.3
13.455	7.4	67	168	84	4.7	42		1/13.5	3.7	3.7	13.5
16	6.2	80	200	100	5.6	50	4	1/16	4.0	4.0	16
19.027	5.3	95	238	119	6.7	59		1/19	4.4	4.4	19
22.627	4.4	113	283	142	8.0	71	.5	1/23	4.8	4.8	22.6
26.910	3.7	135	336	168	9.5	84		1/27	5.2	5.2	26.9
32	3.1	160	400	200	11.2	100	5	1/30	5.6	5.6	32
38.054	2.6	190	476	238	13.4	119		1/38	6.2	6.2	38
45.25	2.2	226	566	283	16	141	.5	1/45	6.7	6.7	45
53.82	1.9	269	673	336	19	168		1/54	7.3	7.3	54
64	1.6	320	800	400	23	200	6	1/60	8.0	8.0	64
76.11	1.3	381	952	476	27	238		1/76	8.7	8.7	76
90.51	1.1	453	1,132	556	32	283	.5	1/90	9.5	9.5	90
107.64	.9	538	1,346	672	38	336		1/108	10.4	10.4	107
128	.8	640	1,600	800	45	400	7	1/125	11.3	11.3	128
152.22	.7	761	1,903	952	53	476		1/152	12.3	12.3	152
181.02	.6	905	2,262	1,131	64	566	.5	1/181	13.5	13.5	181
215.27	.5	1,076	2,690	1,345	75	672		1/215	14.7	14.7	215
256	.4	1,280	3,200	1,600	90	800	8	1/250	16.0	16.0	256
304.4	.3	1,522	3,808	1,904	107	952		1/304	17.4	17.4	304
362.0	.2	1,812	4,526	2,262	127	1,131	.5	1/362	19.0	19.0	362
430.5	.2	2,152	5,380	2,690	151	1,343		1/430	20.7	20.7	430
512.0	.2	2,560	6,400	3,200	180	1,600	9	1/500	22.6	22.6	512
608.9	.2	3,045	7,610	3,808	214	1,904		1/609	24.7	24.7	609
724.1	.1	3,620	9,050	4,525	255	2,263	.5	1/724	26.9	26.9	724
861.1	.1	4,305	10,760	5,380	303	2,690		1/861	29.3	29.3	861
1,024.0	.1	5,120	12,800	6,400	360	3,200	10	1/1000	32.0	32.0	1,024
1,217.7	.08	6,090	15,220	7,610	428	3,805		821 μ	34.9	34.9	1,218
1,448.1	.07	7,240	18,120	9,060	510	4,530	.5	691	38.1	38.1	1,448
1,722.1	.06	8,610	21,520	10,760	605	5,380		581	41.5	41.5	1,722

2^{N_v}	Transmittance c, percent	Electronic flash Q, BCPS	Photoflash L, lumen-sec	Incident light $b \times \pi/r$, ft-candle	Reflected light b, candles/ft^2	Film speed s, ASA	N_v value	t, sec	f, f/no.	D or G ft. or Guide No.	Filter factor, x
2,048.0	0.05	10,240	25,600	12,800	720	6,400	11	488 μ	45.3	45.3	2,048
2,435.5	.04	12,180	30,450	15,225	856	7,610		411	49.3	49.3	2,435
2,896.3	.03	14,490	36,200	18,100	1,018	9,050	.5	345	53.8	53.8	2,896
3,444.3	.03	17,220	43,050	21,520	1,210	10,760		290	58.7	58.7	3,444
4,096.0	.02	20,500	51,200	25,600	1,440	12,800	12	244	64.0	64.0	4,096
4,871.0	.02	24,350	60,900	30,450	1,711	15,220		205	69.8	69.8	4,871
5,792.6	.02	28,970	72,400	36,200	2,035	18,100	.5	173	76.1	76.1	5,792
6,888.7	.01	34,460	86,100	43,050	2,420	21,520		145	83.0	83.0	6,889
8,192	.01	40,950	102,400	51,200	2,880	25,600	13	122	90.5	90.5	8,192
9,742	.01	48,700	121,800	60,900	3,425	30,450		103	98.7	98.7	9,742
11,585	.008	57,900	144,900	72,450	4,075	36,220	.5	86.3	107.6	107.6	11,585
13,777	.007	68,860	172,200	86,100	4,840	43,050		72.6	117.4	117.4	13,777
16,384	.006	81,900	204,900	102,500	5,760	51,200	14	61.0	128.0	128.0	16,384
19,484	.005	97,400	243,500	121,800	6,850	60,900		51.4	139.6	139.6	19,484
23,170	.004	115,900	289,700	144,900	8,145	72,400	.5	43.2	152.2	152.2	23,170
27,555	.004	126,500	344,600	172,300	9,690	86,150		36.3	166.0	166.0	27,555
32,768	.003	163,800	409,500	204,800	11,510	102,400	15	30.5	181.0	181.0	32,768
38,968	.003		487,000	243,500	13,700	121,700		25.7	197.4	197.4	38,968
46,341	.002		579,000	289,800	16,290	144,800	.5	21.6	215.3	215.3	46,340
55,109	.002		688,600	344,400	19,360	172,200		18.1	234.8	234.8	55,109
65,536	.002		819,000	409,500	23,030	204,800	16	15.3	256.0	256.0	65,536
77,935	.001		974,000	487,000	27,400	243,500		12.8	279.2	279.2	77,935
92,681	.001		1,159,000	579,500	32,600	289,800	.5	10.8	304.4	304.4	92,681
110,218	.001		1,265,000	633,000	35,600	316,500		9.9	332.0	332.0	110,218
131,072	.0008		1,638,000	819,000	46,080	409,800	17	7.6	362.0	362.0	131,072
155,871	.0006		1,948,000	974,000	54,800	487,000		6.4	394.8	394.8	155,871
185,362	.0005		2,318,000	1,159,000	65,180	578,500	.5	5.4	430.5	430.5	185,362
220,437	.0005		2,753,000	1,377,000	77,400	688,000		4.5	469.5	469.5	220,437
262,144	.0004		3,278,000	1,639,000	92,200	819,500	18	3.8	512.0	512.0	262,144
311,742	.0003		3,895,000	1,948,000	109,500	974,000		3.2	558.3	558.3	
370,724	.0003		4,638,000	2,318,000	130,400	1,159,000	.5	2.7	608.9	608.9	
440,874	.0002		5,510,000	2,755,000	155,000			2.3	664.0	664.0	
524,288	.0002		6,550,000	3,276,000	184,250		19	1.9	724.1	724.1	
623,483	.0002		7,795,000	3,899,000	219,200			1.6	789.5	789.5	
741,448	.0001				260,700		.5	1.35	861.1	861.1	
881,748	.0001				309,900			1.13	939.0	939.0	
1,048,576	.00010				368,900		20	.95	1,024	1,024	
1,246,967	.00008				438,300			.80	1,116.7	1,116.7	
1,482,897	.00007						.5	.674	1,217.7	1,217.7	
1,763,495	.00006							.567	1,327.9	1,327.9	
2,097,152	.00005						21	.477	1,448.1	1,448.1	
2,493,933	.00004							.401	1,579.0	1,579.0	
2,965,792	.00003						.5	.337	1,722.2	1,722.2	
3,526,990	.00003							.283	1,878.0	1,878.0	
4,194,304	.00002						22	.238	2,048.0	2,048.0	
4,987,866	.00002							.200	2,233.3	2,233.3	
5,931,585	.00002						.5	.169	2,435.5	2,435.5	
7,053,980	.00001							.142	2,655.8	2,655.8	
8,388,608	.00001						23	.119	2,896.3	2,896.3	
9,975,733	.00001							.100	3,158.0	3,158.0	
11,863,169	.00001						.5	.084	3,444.3	3,444.3	
14,107,961	.00001							.071	3,756.0	3,756.0	
16,777,216	.00001						24	.060	4,096.0	4,096.0	
19,951,465	.00001							.051	4,466.7	4,466.7	
23,726,339	.00001						.5	.042	4,871.0	4,871.0	
28,215,922	.00001							.036	5,311.7	5,311.7	
33,554,432	.00001						25	.030	5,792.6	5,792.6	
39,902,931	.00001							.025	6,316.0	6,316.0	
47,452,678	.00001							.021	6,888.7	6,888.7	
56,431,844	.000002							.018	7,512.1	7,512.1	
							26	.015			
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